

Arctic Convective Cloud Feedback Studies with the CESM

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Randall

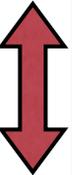
CMMAP Summer 2012 Team Meeting

Introduction

Observations: Very warm climate 146-34 Myr ago
(Cretaceous/Paleocene/Eocene)

- High global mean temperature
- Low equator-pole temp diff (~25°C, now ~45°C)
- No significant ice
- Tropical SSTs >= modern
- Warm deep ocean (15°C)
- CO₂ = 500-5000ppm ??

EON	ERA	PERIOD	EPOCH	Ma	
Phanerozoic	Cenozoic	Quaternary	Holocene	0.01	
			Pleistocene	Late	0.8
		Early		1.8	
		Tertiary	Pliocene	Late	3.6
				Early	5.3
			Miocene	Late	11.2
				Middle	16.4
			Oligocene	Early	23.7
				Late	28.5
		Eocene	Early	33.7	
			Late	41.3	
			Middle	49.0	
			Early	54.8	
		Paleocene	Late	61.0	
	Early		65.0		
	Mesozoic	Cretaceous	Late	99.0	
			Early	144	
		Jurassic	Late	159	
			Middle	180	
		Triassic	Early	206	
			Late	227	
		Permian	Middle	242	
			Early	248	
		Paleozoic	Permian	Late	256
				Early	290
	Pennsylvanian			323	
			Mississippian		354
	Devonian		Late	370	
			Middle	391	
	Silurian		Early	417	
			Late	423	
	Ordovician		Early	443	
Late			458		
Cambrian	Early	470			
	Early	490			
	D	500			
	C	512			
Precambrian	Proterozoic	B	520		
		A	543		
		Late	900		
	Archean	Middle	1600		
		Early	2500		
Archean	Late	3000			
	Middle	3400			
	Early	3800?			

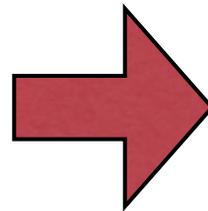


Proposed Mechanism

a qualitatively different state of the atmosphere, with tropical-like deep atmospheric convection and high tropospheric clouds at mid- to high-latitudes providing a strong greenhouse effect

warmer surface

- unstable air column
- deep convection
- high clouds
- greenhouse effect
- warmer surface



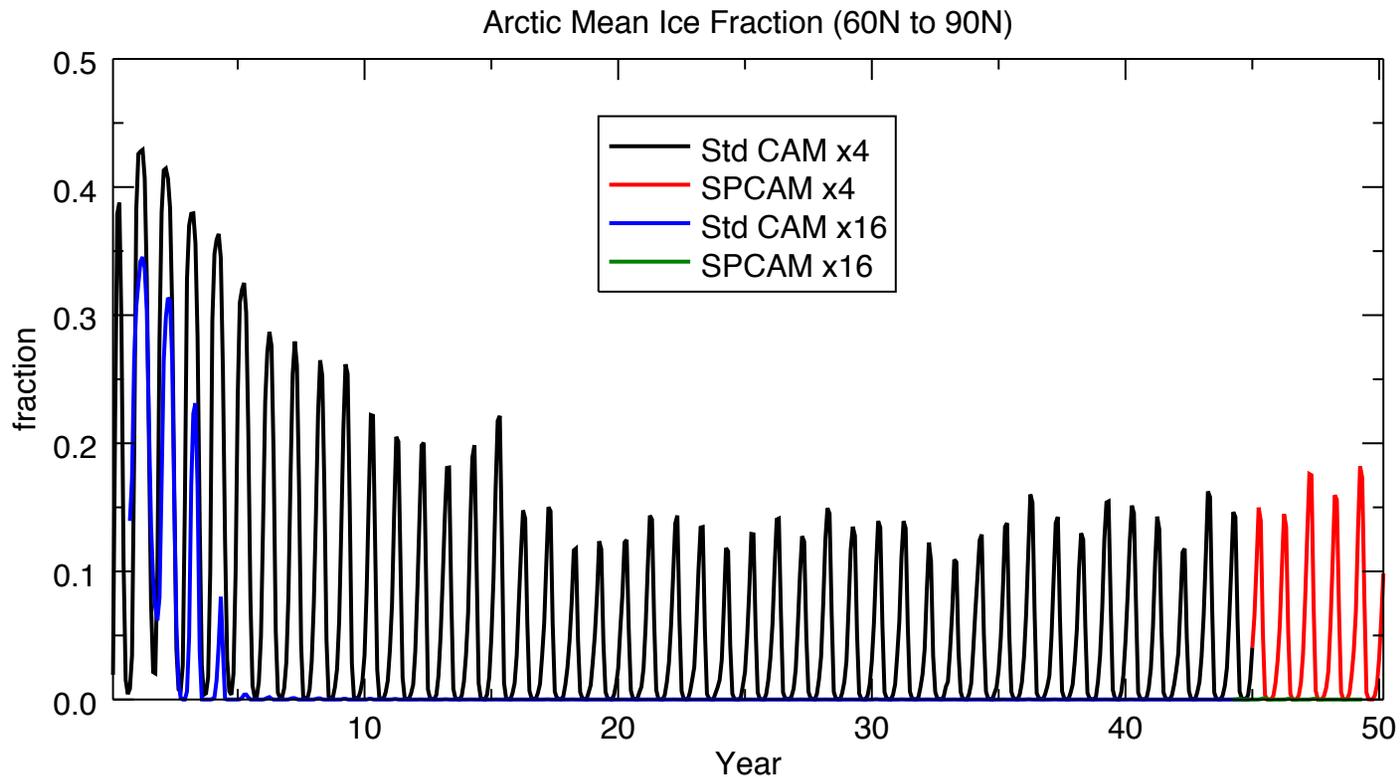
Positive feedback!

may also be relevant for future greenhouse scenarios

Previous Work

Standard CAM + slab ocean model followed by
SPCAM + slab ocean model for:

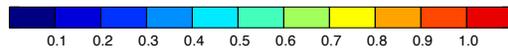
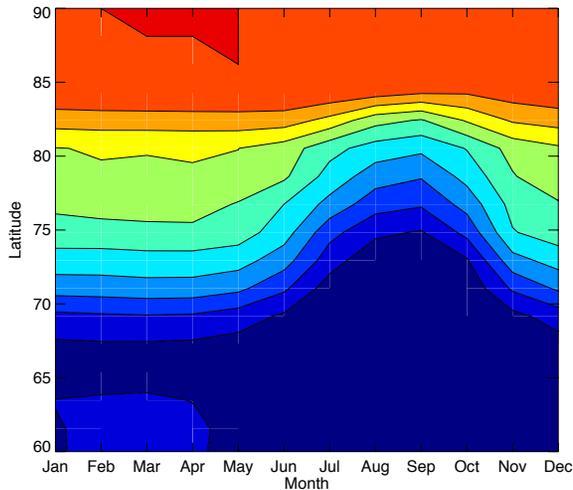
- 16xPI CO₂ concentration
- 4xPI CO₂ concentration



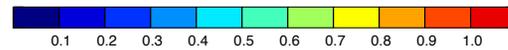
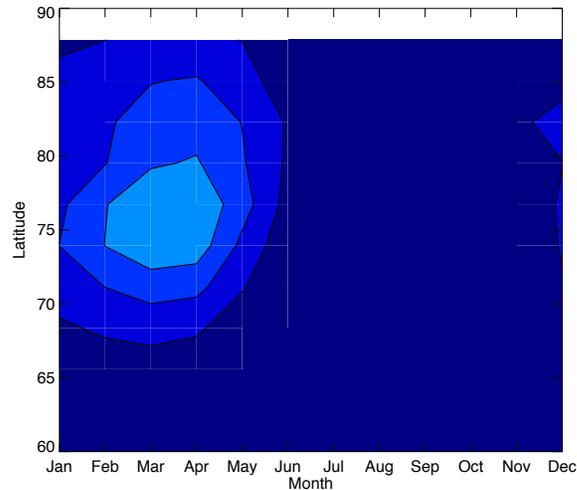
Preliminary CAM and SPCAM results

Sea ice fraction

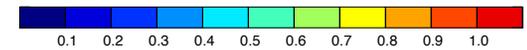
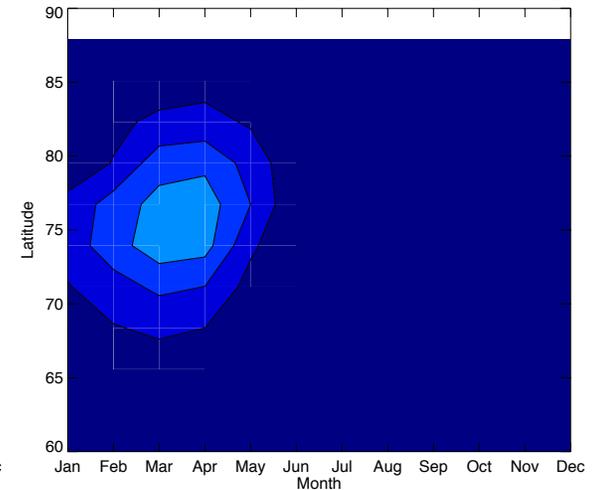
CAM,x1CO2



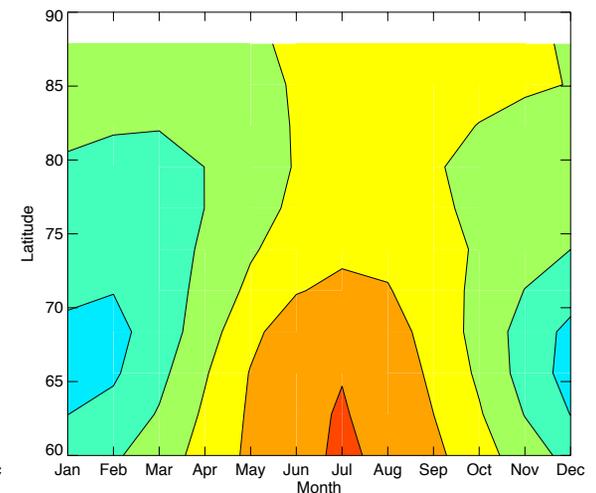
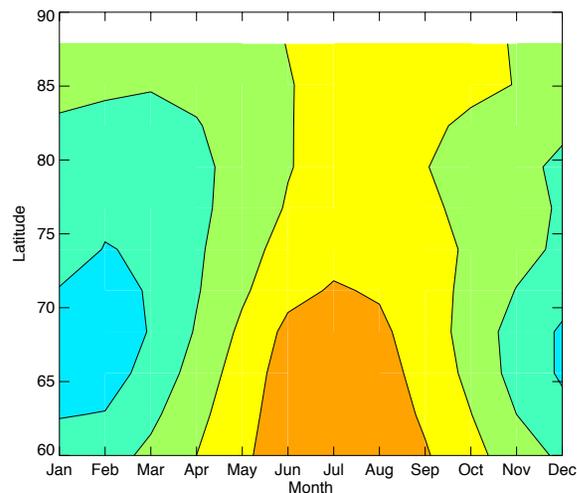
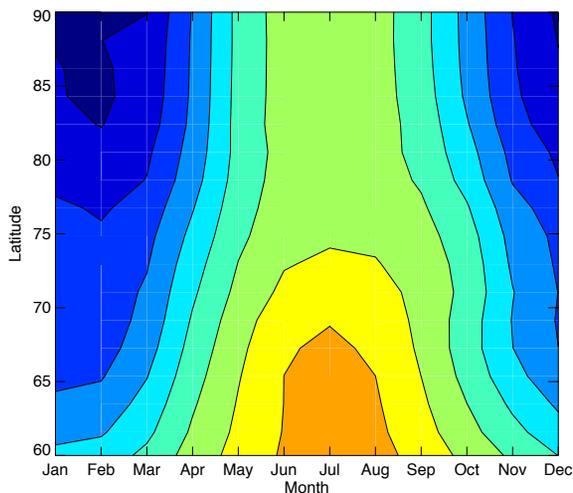
CAM,x4CO2



SPCAM,x4CO2



Surface temp



Preliminary CAM and SPCAM results

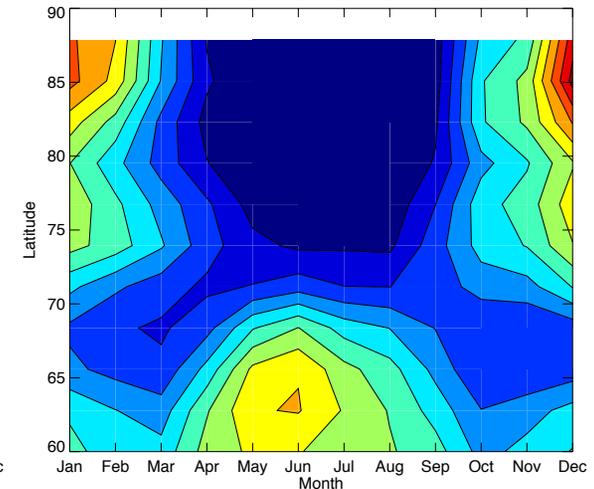
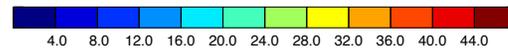
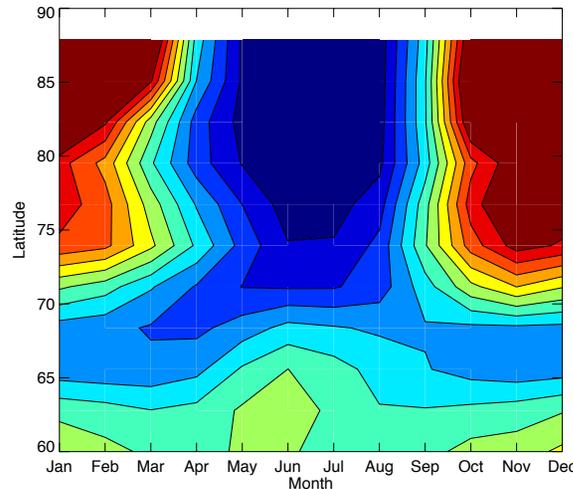
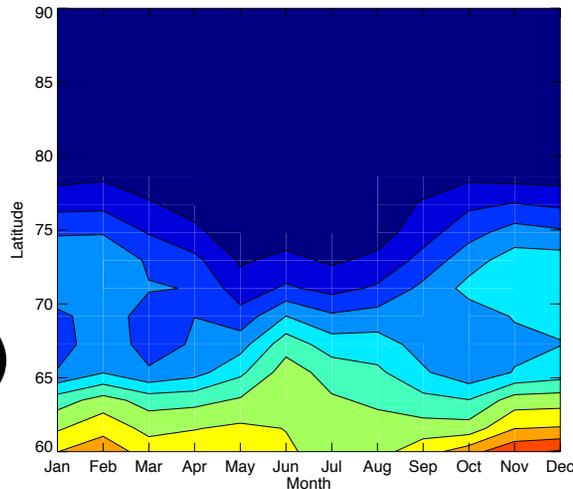
CAM,x1CO2

CAM,x4CO2

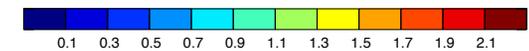
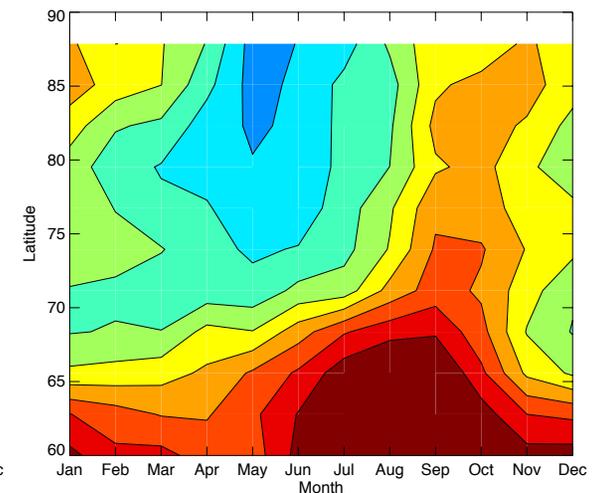
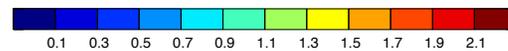
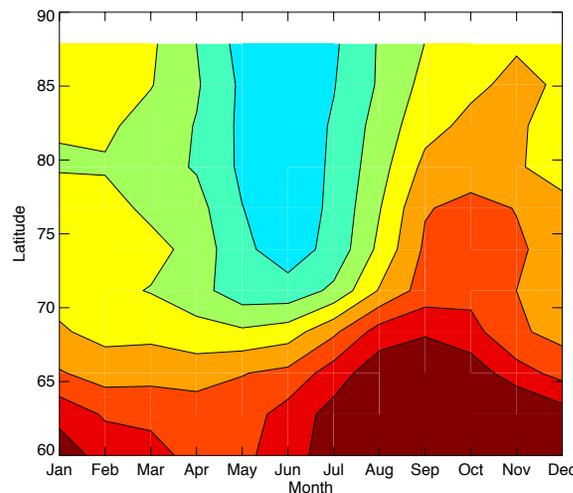
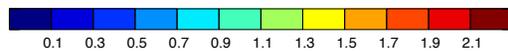
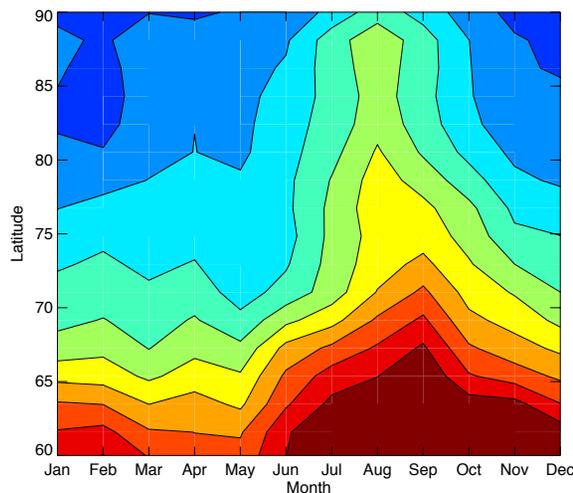
SPCAM,x4CO2

Conv
mass
flux
(hPa/day)

max value
in column



Total
precip



Next Step

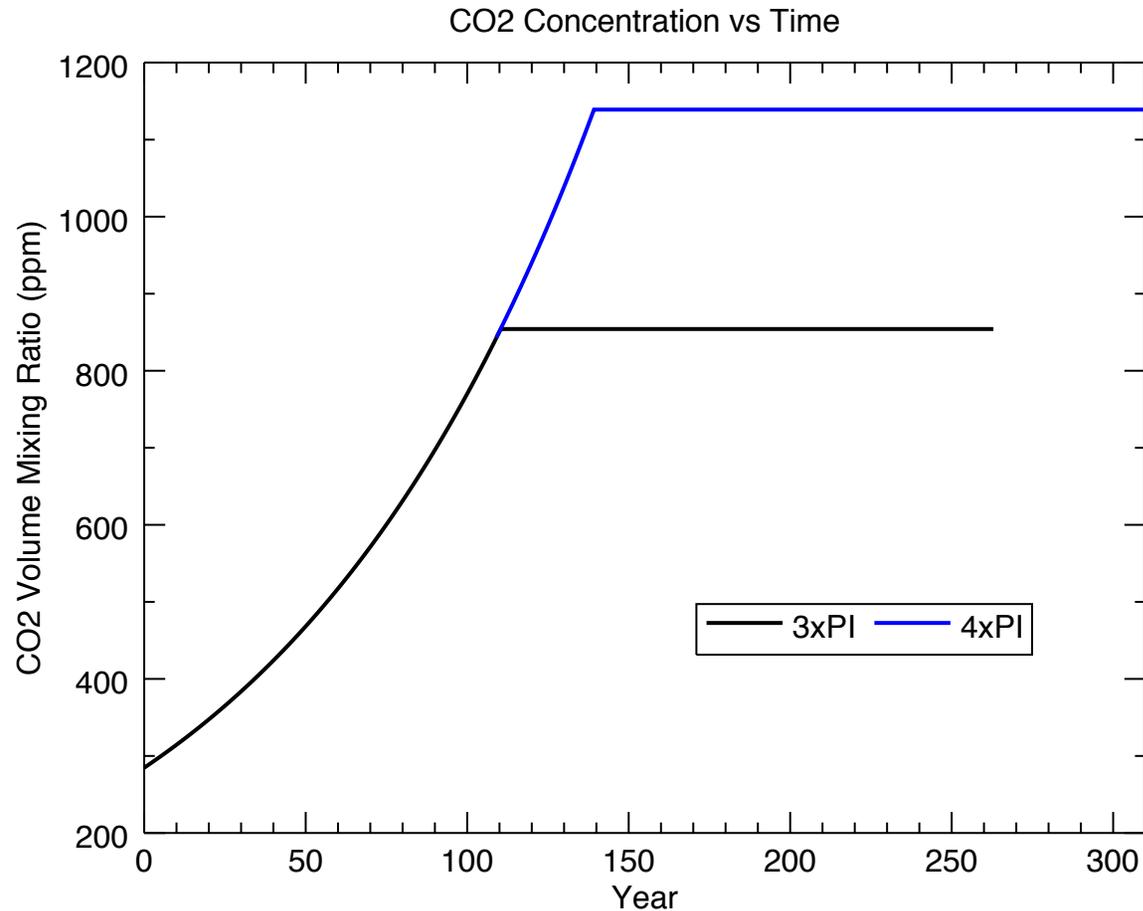
- **GOAL:** Identify the transient vs equilibrated response of the feedback during a transient simulation of increased CO₂ concentration
 1. Run the fully-coupled Community Earth System Model (CESM) for a transient CO₂ scenario
 2. Run shorter (~10-20 year) SPCAM/SPCESM simulations taken from CESM snapshots
 - when Arctic sea ice has decreased to 50% of initial value
 - at end of CESM simulation (fully equilibrated)

CESM Simulation

- Fully-coupled CESM1.0.2, CAM4 Physics, Finite Volume dynamical core
- $1.9^{\circ} \times 2.5^{\circ}$ grid for atmos and land components with the gx1v6 displaced pole grid for ocean and ice
- 25-year spinup simulation holding all trace gases constant
- Followed by 1% per year CO₂ increase

CESM Simulation

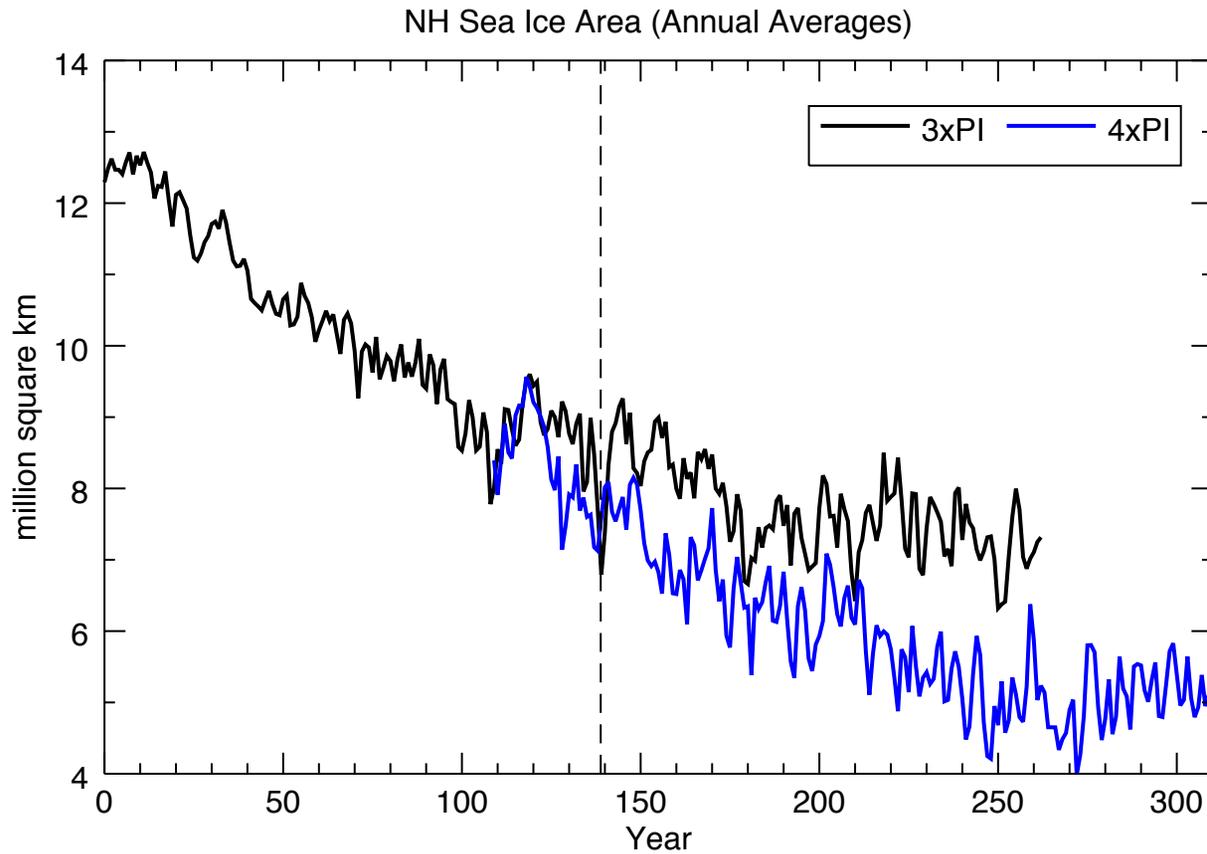
- Branch the simulation at the 3xPI point, allow branch to reach 4xPI



NH Sea Ice Areal Extent Time Series

3xPI was hit in year 110

4xPI was hit in year 140

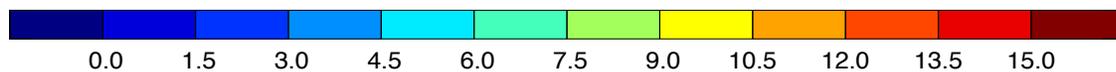
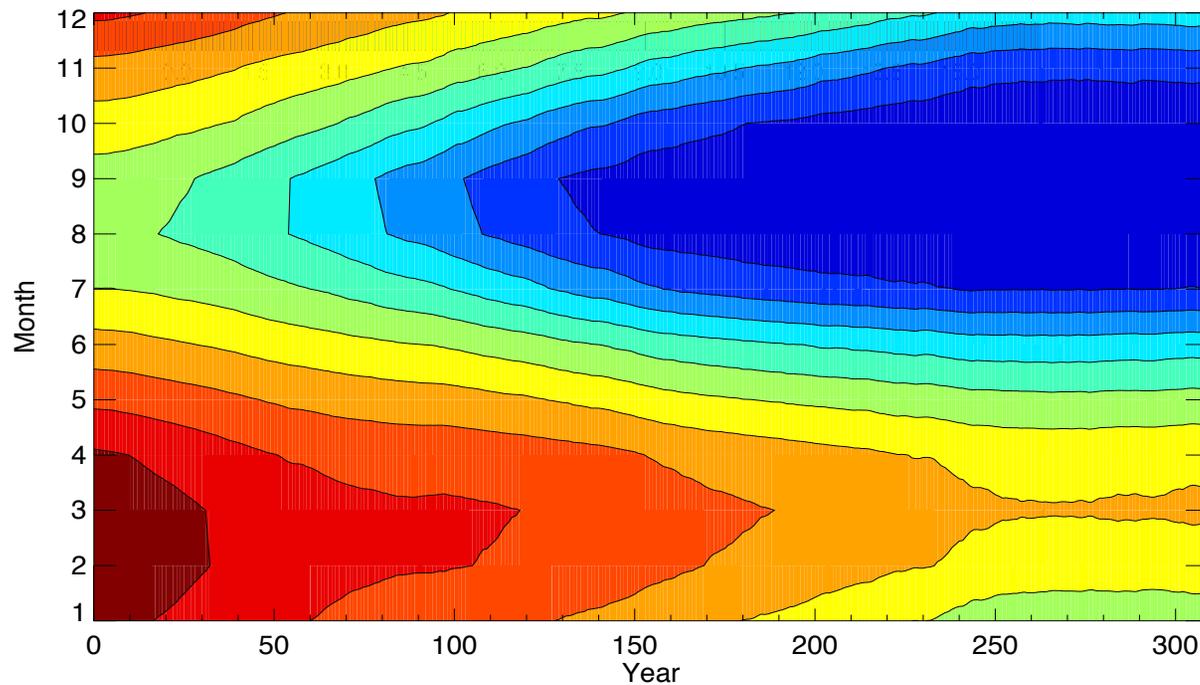
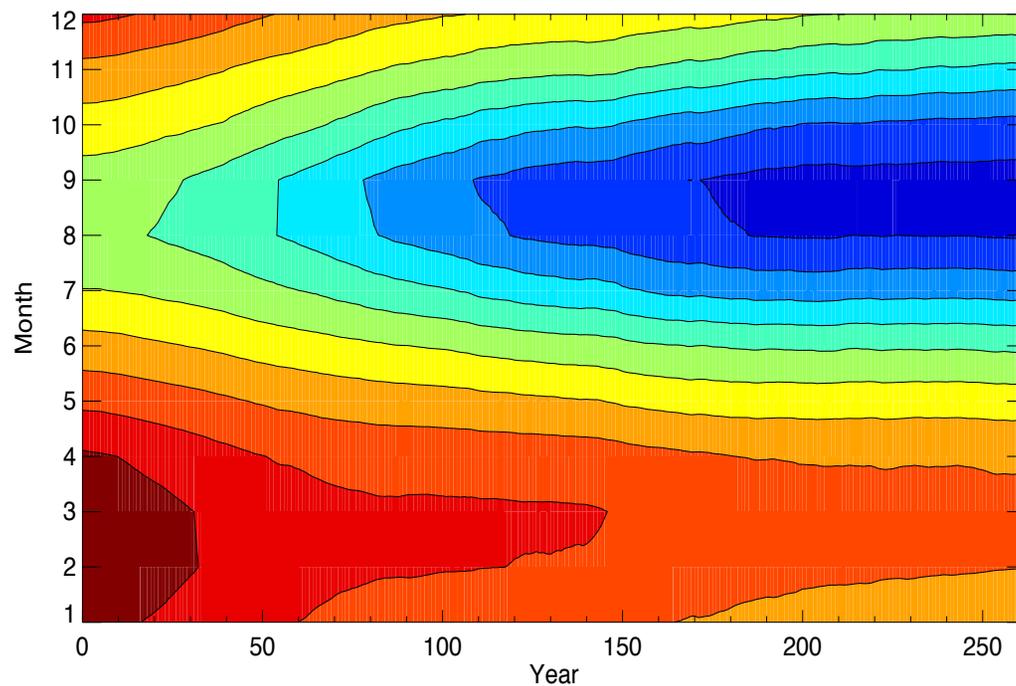


3xPI

Sea Ice Area
(million km²)

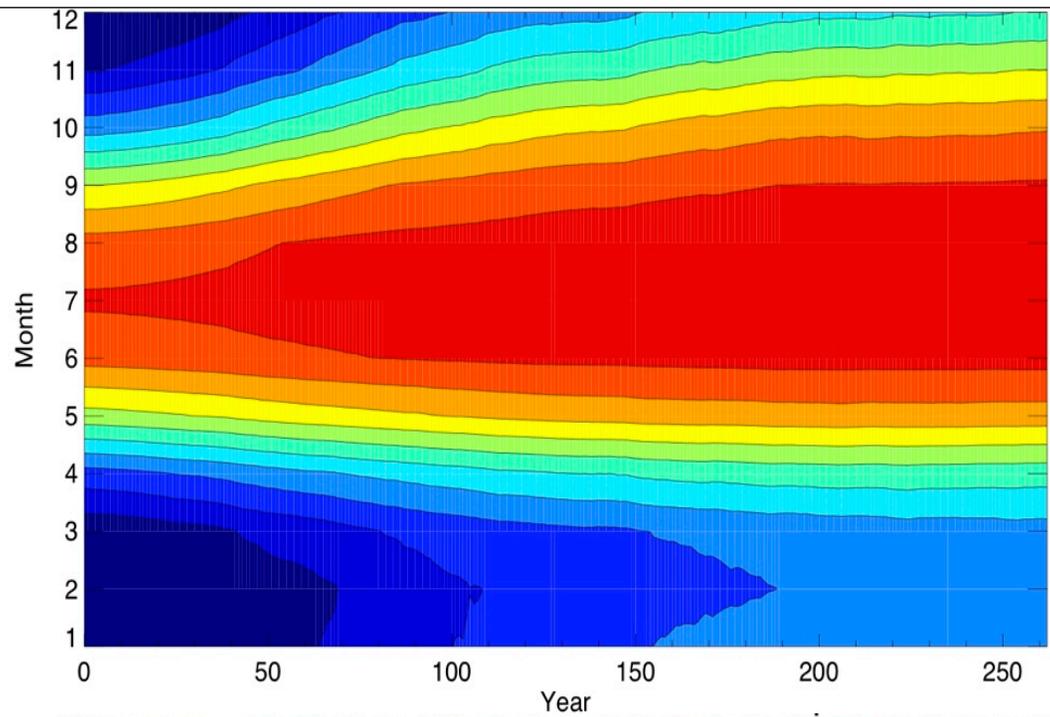
4xPI

70N-90N mean
5-year smoothed

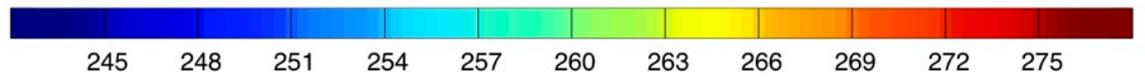
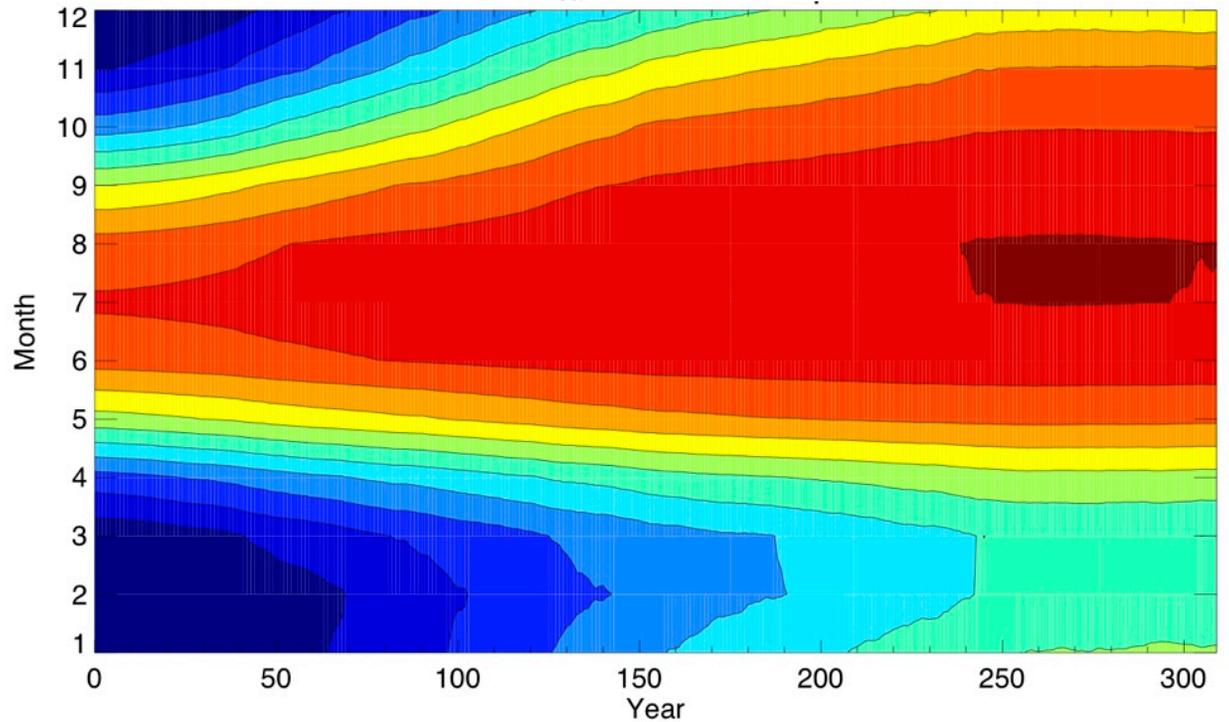


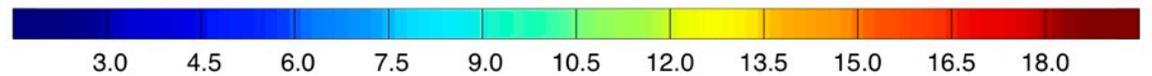
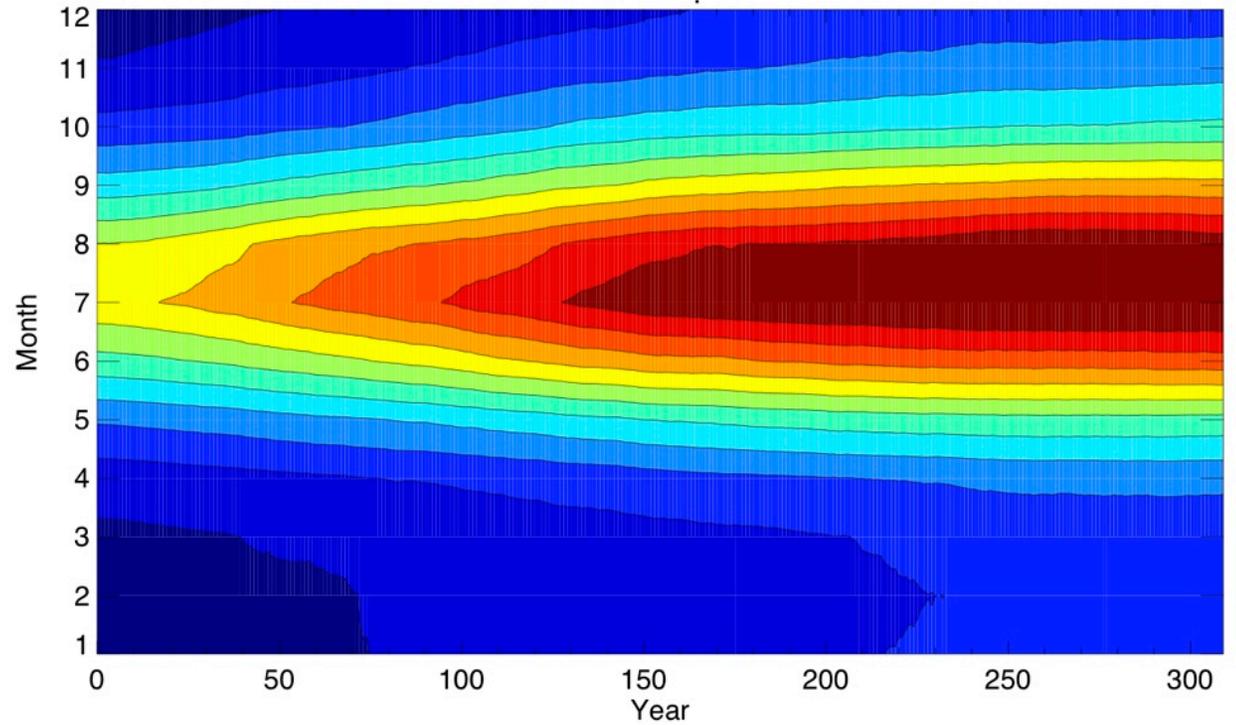
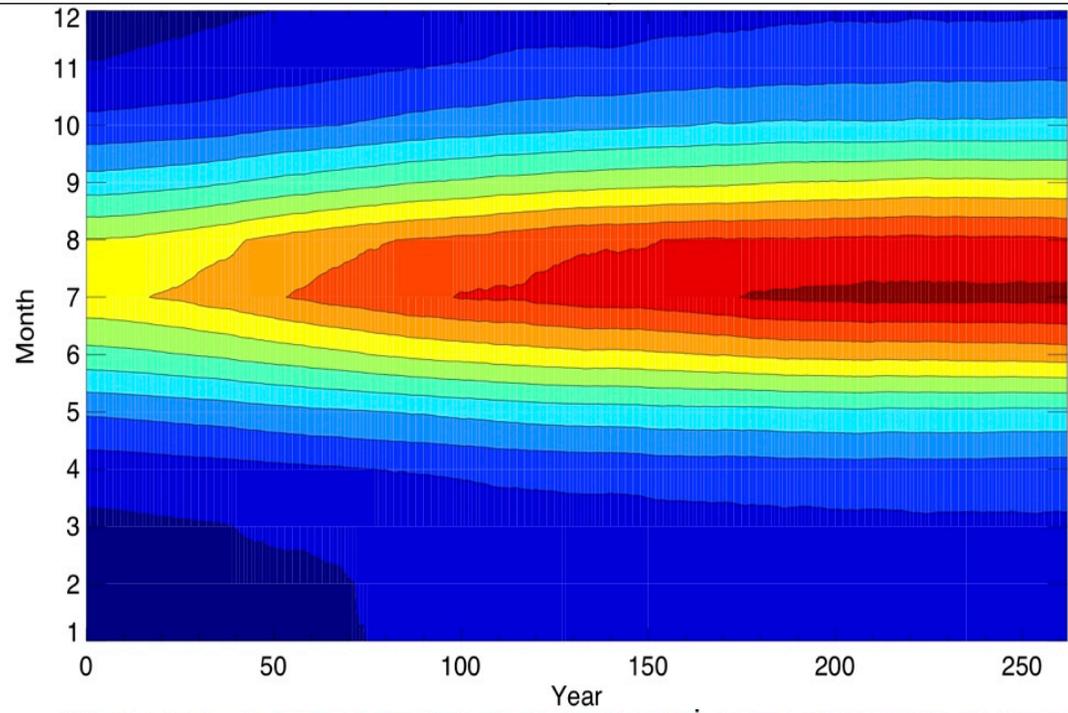
3xPI

Surface
Temperature
(K)



4xPI





3xPI

Precipitable Water
(kg/m²)

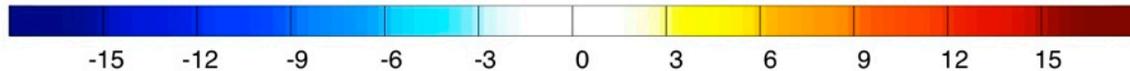
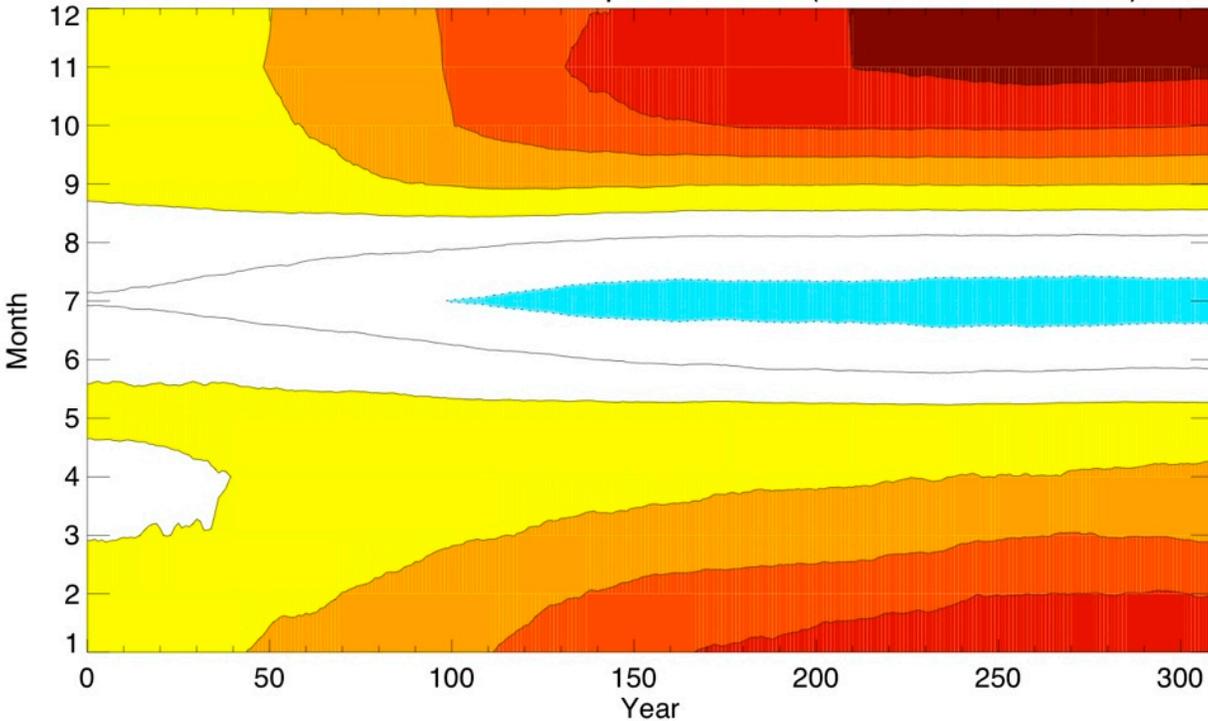
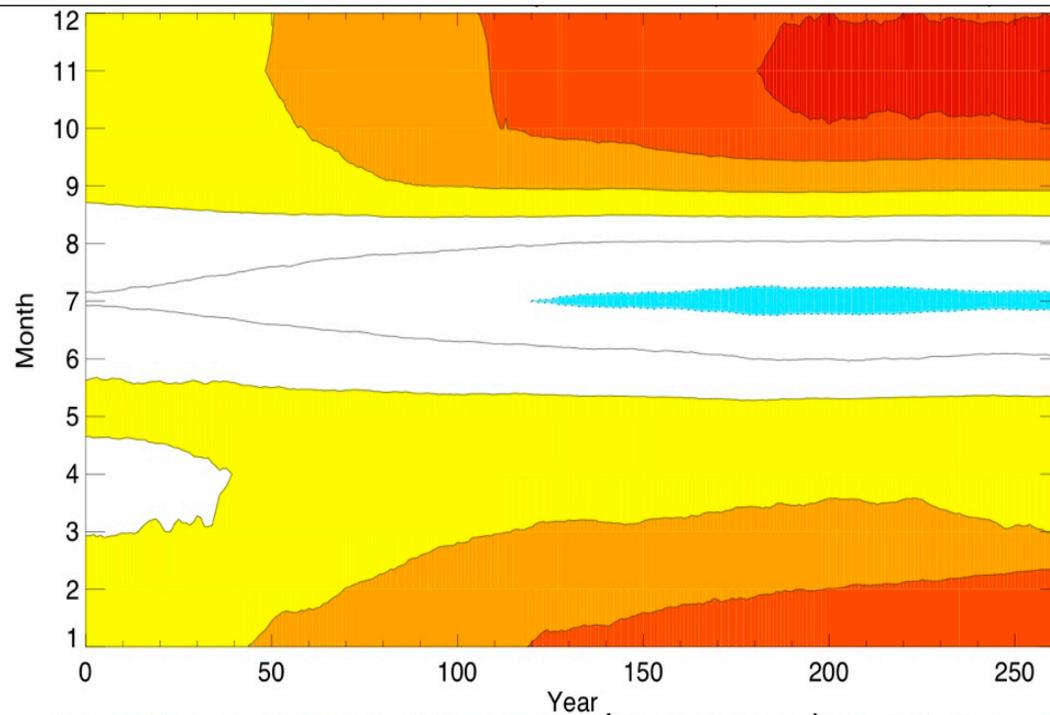
4xPI

3xPI

Sfc Temp Difference
(K)

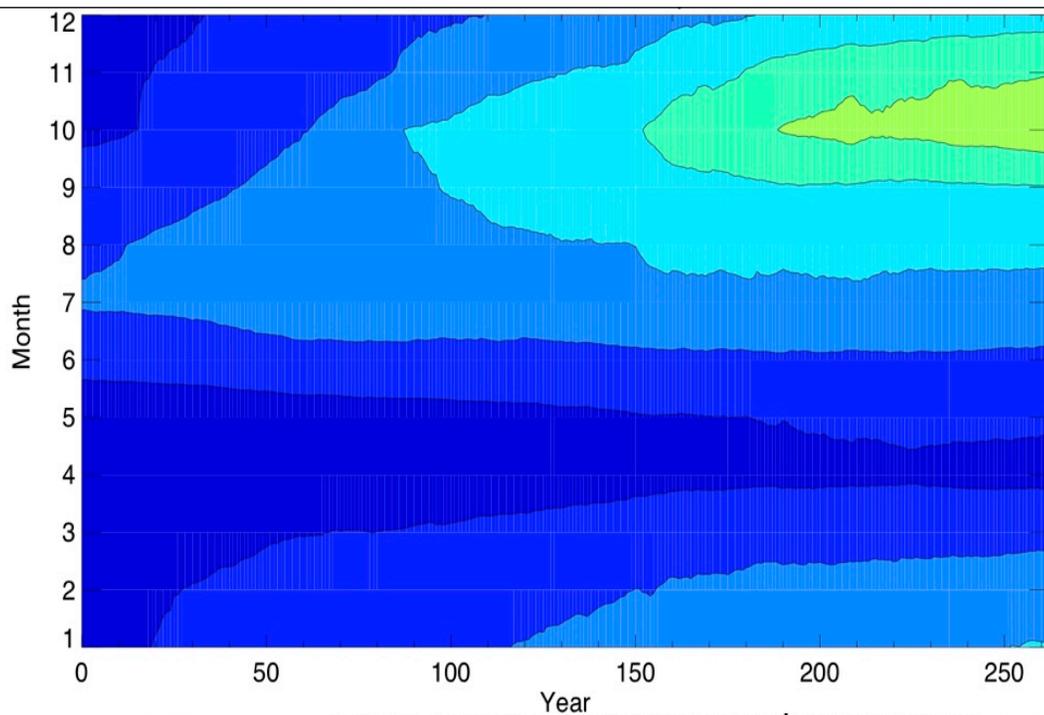
ocean/ice - land

4xPI

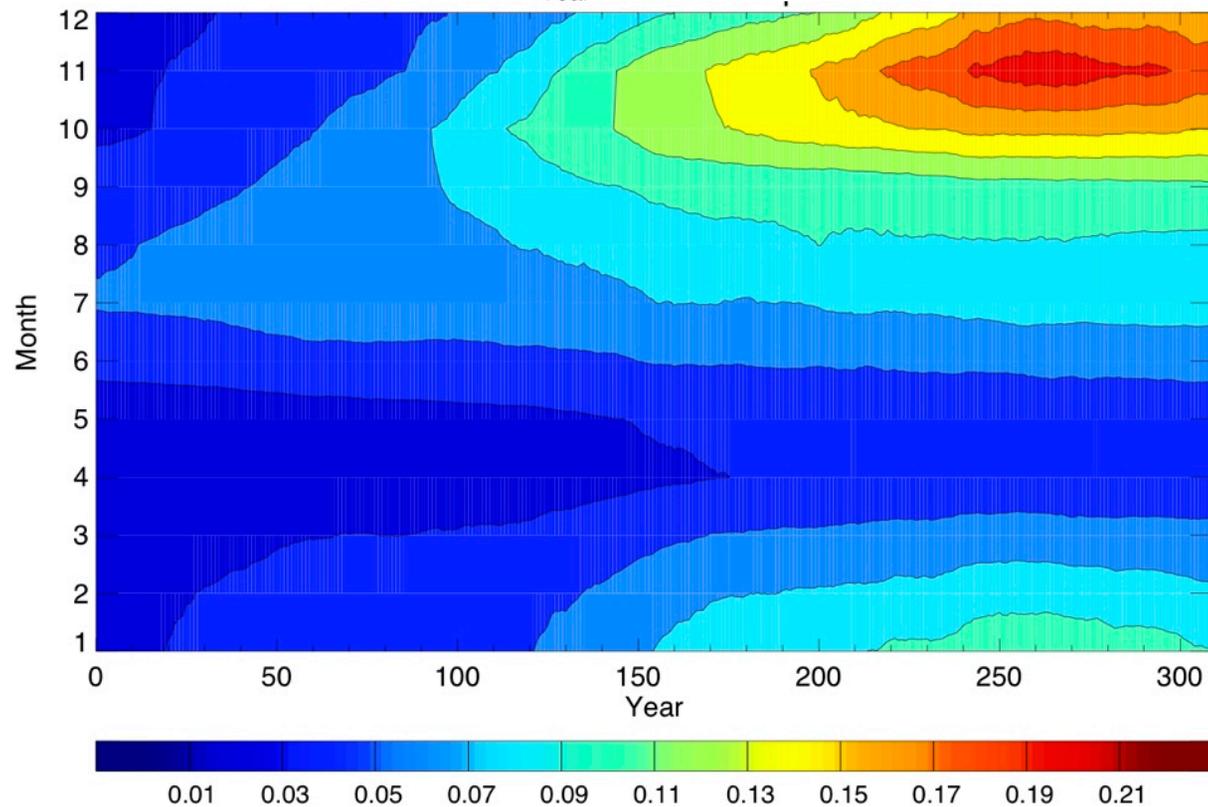


Convective Precip (mm/day)

3xPI



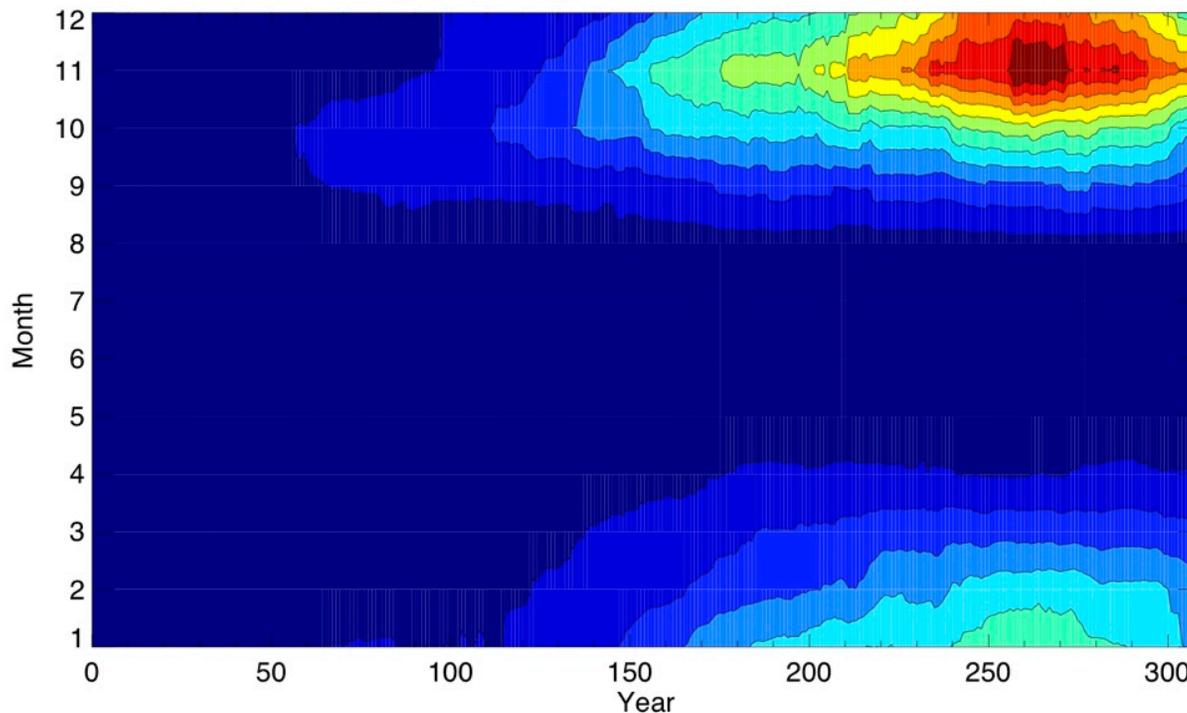
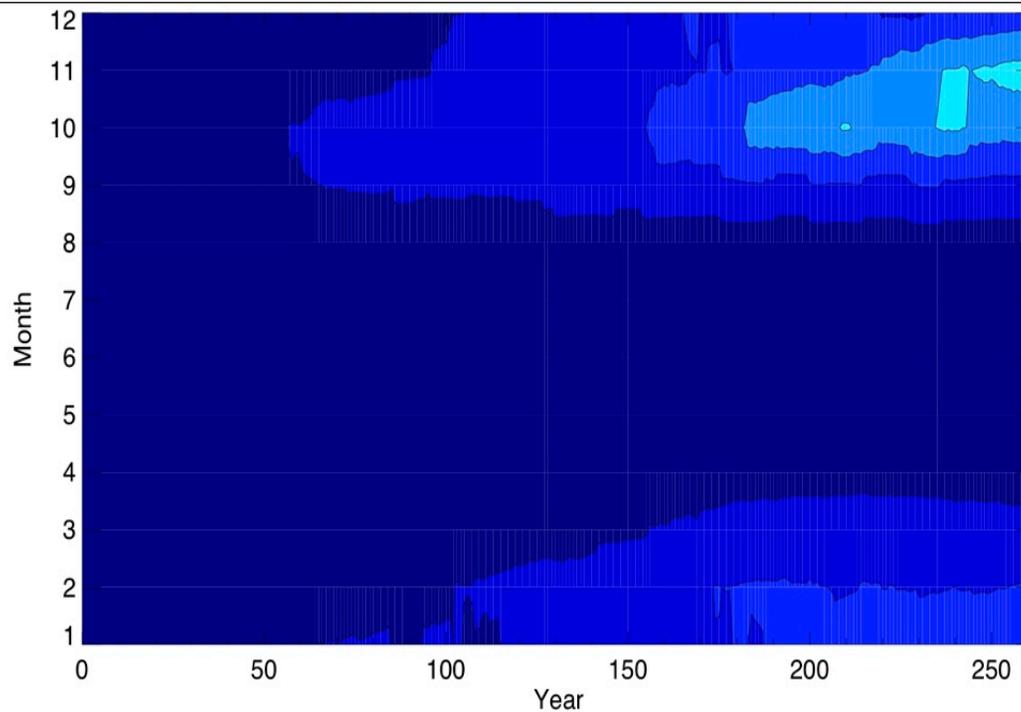
4xPI



3xPI

CAPE
(J/kg)

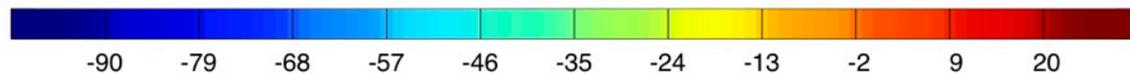
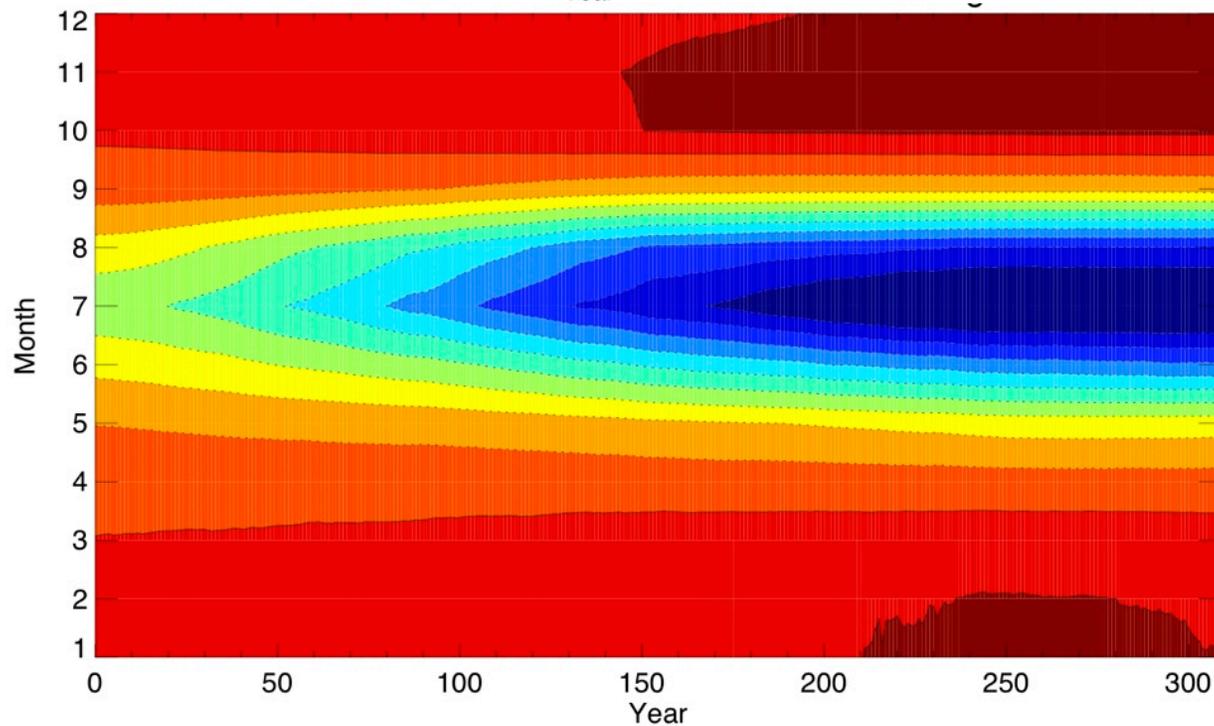
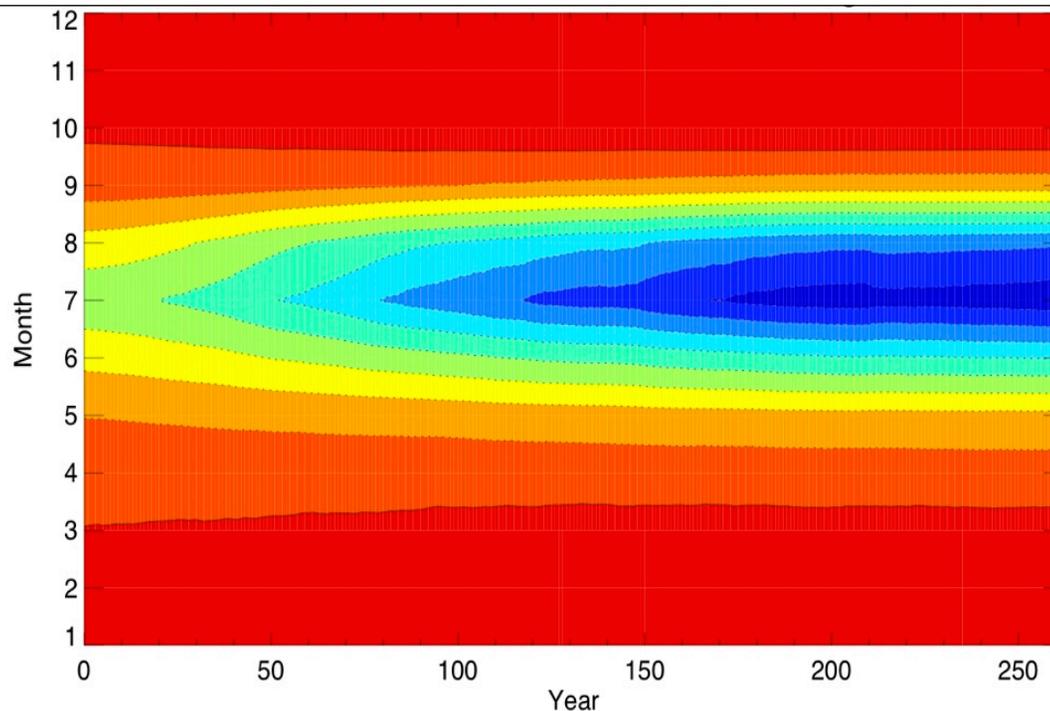
4xPI



3xPI

Total Cloud Forcing
(W/m^2)

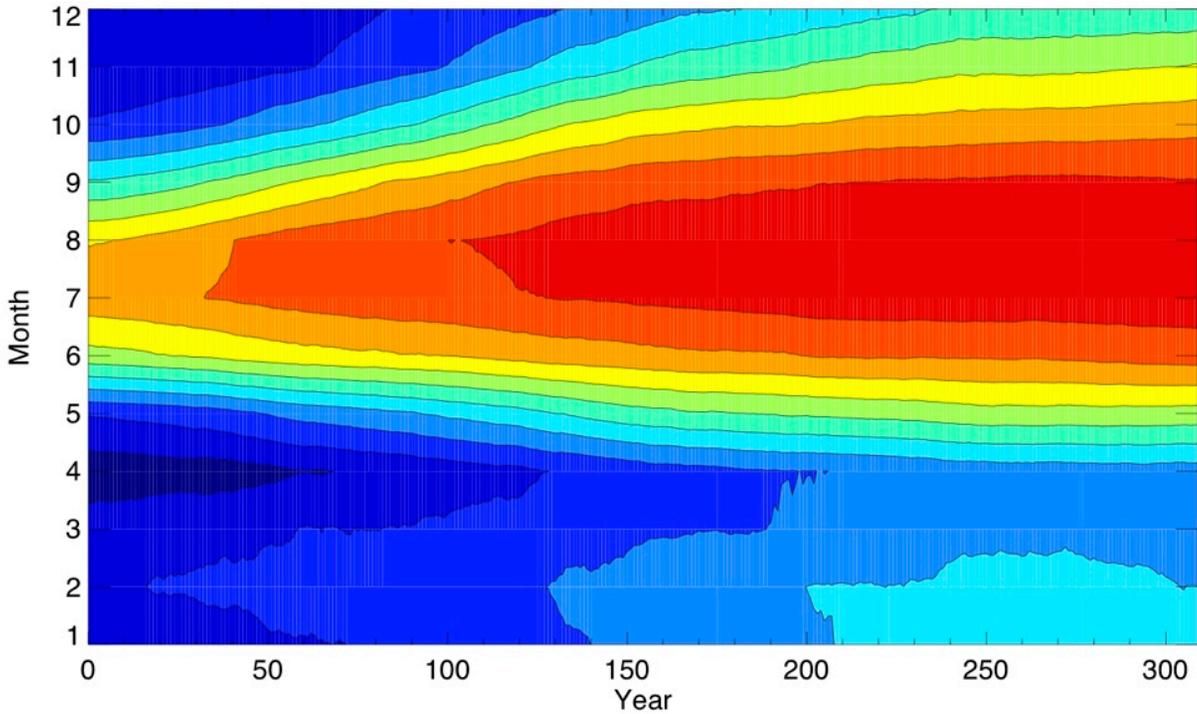
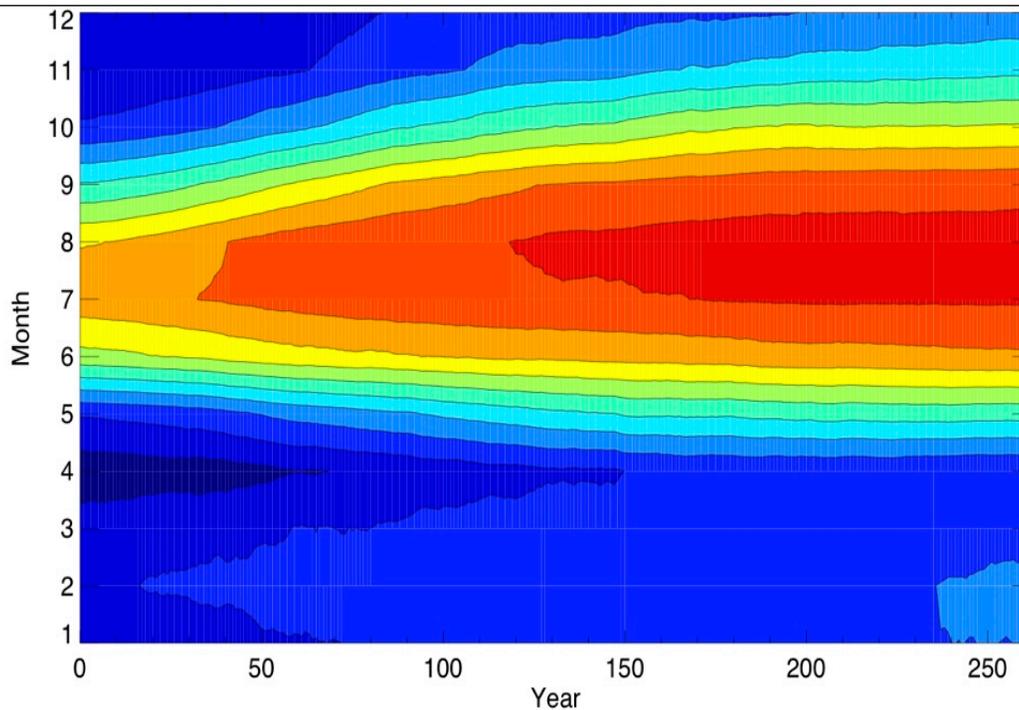
4xPI



3xPI

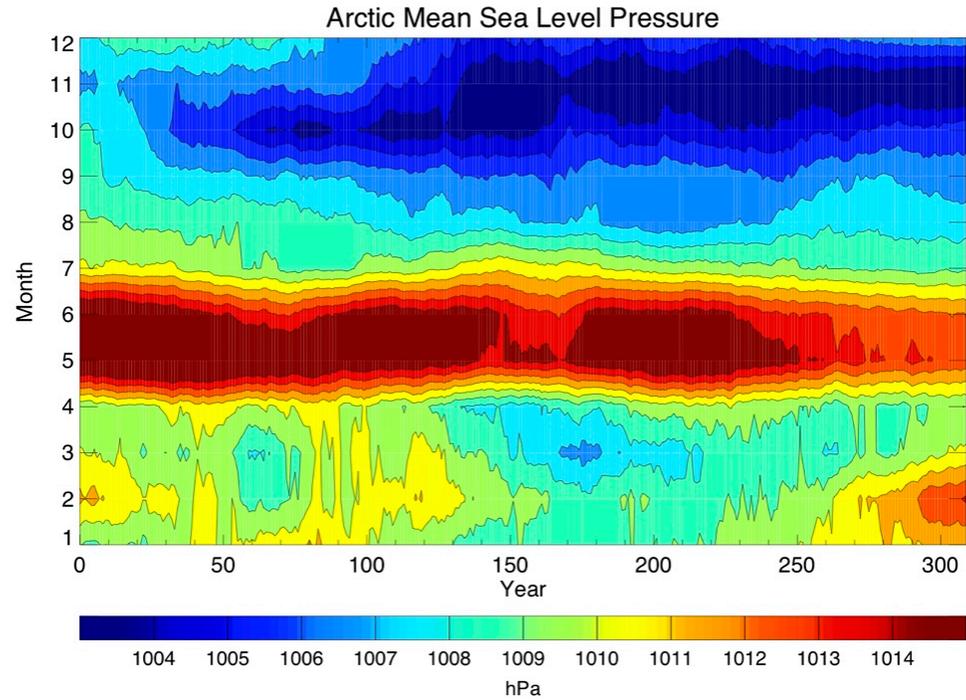
Total Cloud Amount
(fraction)

4xPI

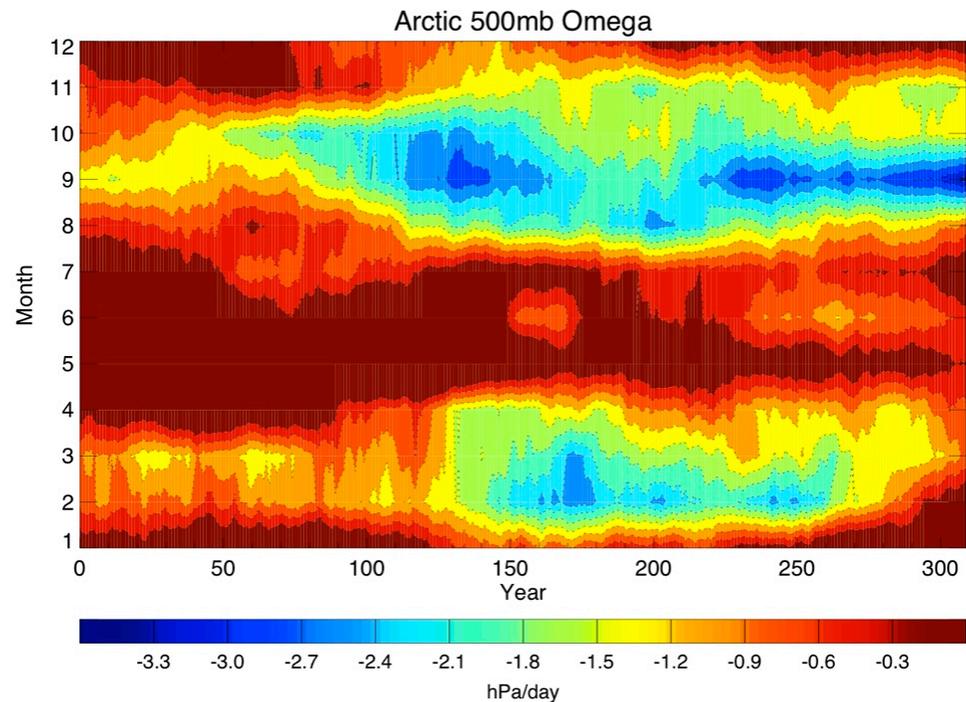


4xPI only!

Sea Level Pressure
(hPa)



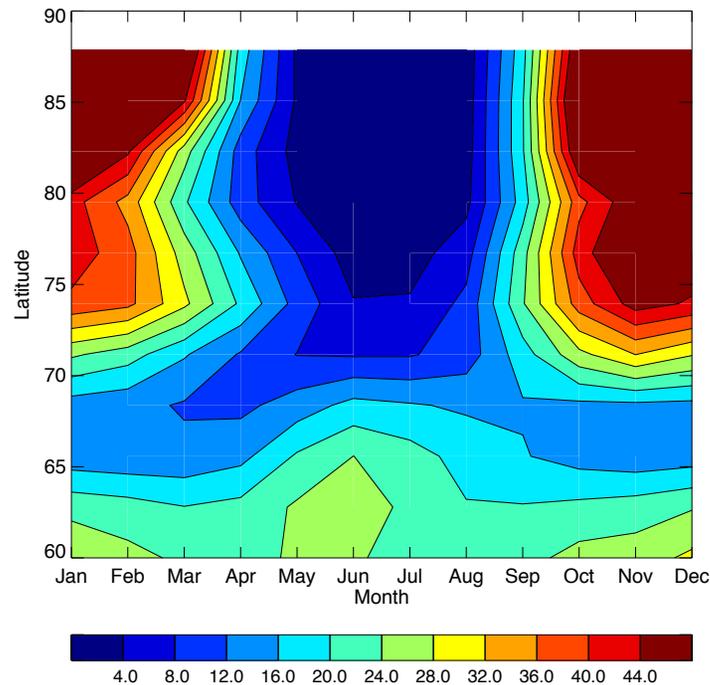
500mb Omega
(hPa/day)



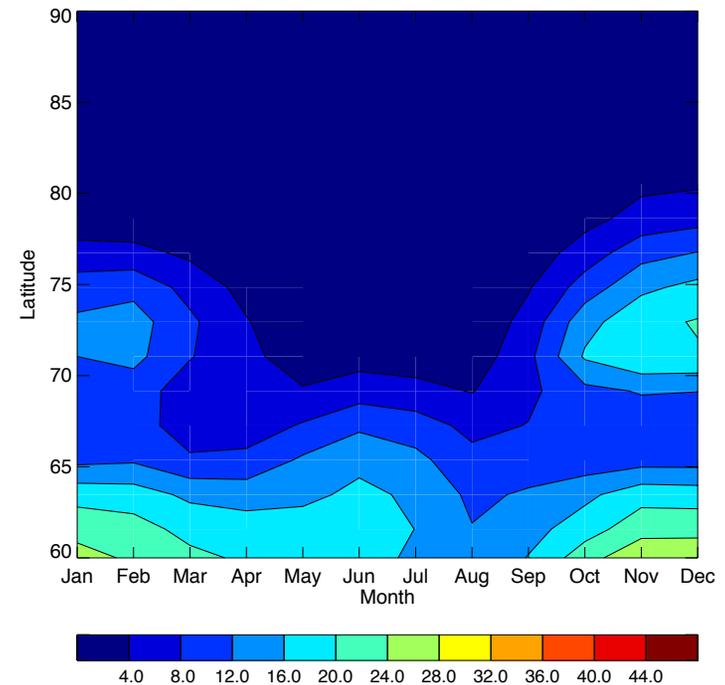
Convective mass flux (hPa/day)

Convection seems much weaker in CESM (CAM4) versus CAM3 results

CAM3.5,x4CO2



CESM, years 300-310

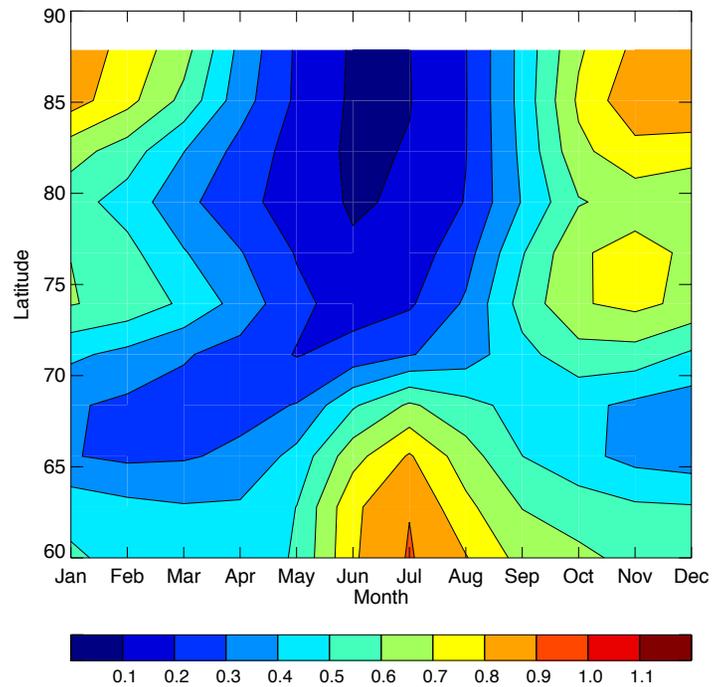


max value in column

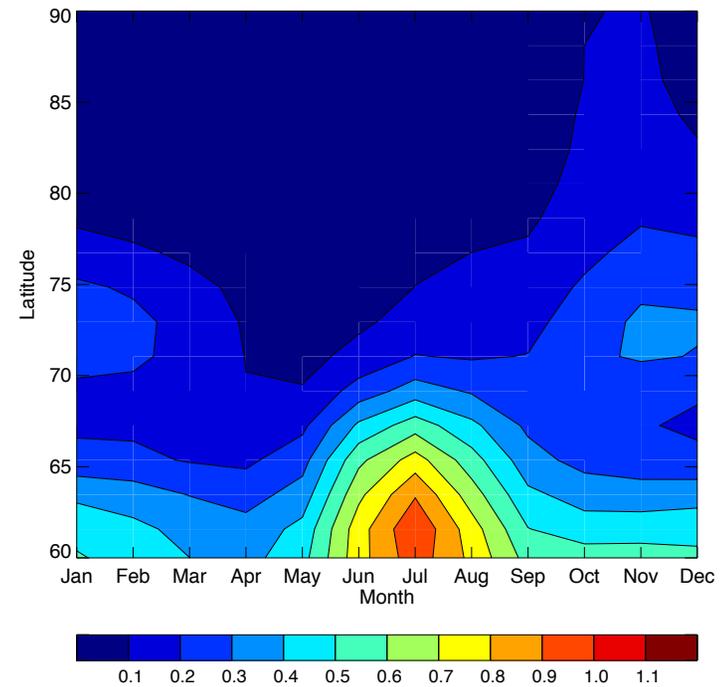
Convective Precipitation Rate (mm/day)

Little to no increase in winter convective precip compared to CAM3.5

CAM3.5,x4CO2



CESM, years 300-310



Next Steps

- More analysis of CESM simulation results
- Run SPCAM/SpCESM from restart files at selected points from the long-term CESM simulation(s)
- Integrate SPCAM with Eocene boundary conditions from previously run simulations (provided by Matt Huber)